Forecasting Research

Forecasting Research Division
Technical Report No. 46

An atlas of fetch-limited wave height over the North Sea

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Introduction

Forecasts of sea state, whether made by human forecaster or numerical model, depend critically upon the input wind speed and direction. A difference of several degrees in direction between the forecast wind used in the calculations and the actual wind experienced may lead to quite a different sea state, if one direction is blowing over a different fetch due to details of the local coastline. Further, numerical models are limited by the spatial resolution of their coastline, and what is in reality a fetch of several hundred kilometers may appear to the model to be fifty kilometers more or less than that, with a consequent impact on forecast wave heights. The direction resolution of the UKMO numerical wave models is currently 22.5 degrees (16 components) and there may also be numerical truncation effects (the so-called 'garden sprinkler' effect) when the model wind direction is not directly along a direction component.

Accordingly, to estimate the potential impact of these limitations, and to provide a reference guide on wave model performance for forecasters and for future development, an atlas of fetch limited wave height over the North Sea has been prepared using the UKMO wave model at the resolution of the European waters grid. This report describes the contents of the atlas and highlights several interesting features. The complete atlas is available as a separate Forecasting Research Division Internal Note.

1 The Atlas

Charts of fetch limited wave height over the North Sea were calculated using the UKMO wave model at the resolution of the European waters grid, which is 0.4 degrees longitude by 0.25 degrees latitude. The wave model used 16 direction components, giving a directional resolution of 22.5 degrees. Shallow water effects were not included. The charts are for a (19.5m) windspeed of 15m/s, blowing for a duration of 60 hours. The fully developed wave height is 4.77m. Charts are shown of wave height over the full model area with a contour interval of 0.5m, at 10 degree intervals of wind direction. The direction in the title is 'wind direction FROM' in degrees.

Difference charts of wave height between adjacent wind directions are also presented for the North Sea and UK coastal waters. Here the contour interval is 0.1m and positive differences are shaded at intervals of 0-0.2m, 0.2-0.4m and >0.4m .

Figure 1 shows the model gridpoints over the North Sea area. Points marked with a '2' are coast points. At these points there is no calculation of wave energy growth - the coast points act as a sink of onshore wave energy for the model advection scheme, and for offshore winds have zero

wave energy. The open Atlantic boundary points in the model act as coast points in these runs, as no boundary data was specified.

2 Interesting features

Figure 2a shows the model wave heights for a wind from 270°. The increasing wave height with distance offshore is clearly shown, as is the reduction in wave height downwind of the Faeroes and the Shetland Isles. This may be affected by the directional resolution of the model. The detail of the Peterhead peninsula on wave height is noticable across the North Sea. Figure 2b shows the wave heights for a wind from 110°. Here the extra fetch in the eastern North Sea for winds blowing out from the Skagerrak is shown by the tongue of higher waves there.

Figure 3 shows a selection of difference charts of wave height between adjacent wind directions. Figure 3a shows the impact of a 10° difference in wind direction between 270° and 260°. Forecasters at Aberdeen Weather Centre have commented on the wave model performance for the Buchan Field (58N, 0E) when the wind is south of west. The NWP winds forcing the wave model tend to be too meridional and do not capture the local lee troughing. The actual winds in such cases come more from the south, running parallel to the Grampian/Tayside coast and giving a much increased fetch. Figure 3a shows the complex differences in wave height in this area, with some areas up to 70cm different. With the wind from 260° the fetch down the Moray Firth (north of the peninsula) to Buchan is much reduced from that for a wind from 270°. The detailed shadowing effect of the Shetland Islands is also clear.

Figure 3b shows the wave height differences for a 10° wind shift between 230° and 220°. Now the peak differences are further north, and there is a tight gradient of wave height difference, with a difference of 1m wave height across only some 100km, caused by the windshift. The detail is sensitive to the wind direction compared to the direction of the Grampian / Tayside coast.

Figure 3c shows the increased shadowing effect of Orkney and the Shetland islands once the wind is from due south. Also it is clear that for wind from 180° rather than 190° the seas are much higher to the north west of the Orkney-Shetland gap.

Figure 3d shows further the downstream influence of the Orkney-Shetland gap ,for winds from 170°. The influence of the northern tip of Spain is seen extending north into the bay of Biscay.

Figure 3e shows the effect of the wind shadow of the Norwegian coast extending across the North Sea to the Shetland Islands, for a windshift from 080° to 070°.

3 SUMMARY

The atlas has demonstrated the sensitivity of wave model forecast sea states to the resolution of the coastline and wind direction. It is hoped that forecasters may find the information useful in their interpretation where they notice a persistent discrepancy between model forecast and actual sea states. The difference charts in particular highlight those areas of the North Sea that are sensitive to small changes in direction for a given wind.

The impact will be less for lighter winds, as lower windspeeds require less fetch to achieve fully developed waves, and the equilibrium wave height is lower. For stronger winds the effects may be more pronounced than demonstrated here.

Shallow water effects were not included in the model for these calculations. In strong winds the sea state, particularly in the southern North Sea, will be further modified by the effects of wave refraction and dissipation of wave energy by bottom friction.

Future work will assess the benefit of increasing directional resolution on fetch limited wave growth in the wave model.

FIGURES

Figure 1 Gridpoint types

Figure 2 Wave heights for windspeed 15m/s. Contour interval 0.5m
- a) for wind from 270°
- b) for wind from 110°

Figure 3 Charts of difference in wave height. Contour interval 0.1m, positive differences shaded at intervals of 0-0.2m, 0.2-0.4m and >0.4m
- a) Wind 270° - 260°
- b) wind 230° - 220°
- c) wind 190° - 180°
- d) wind 170° - 160°
- e) wind 080° - 070°

Figure 1

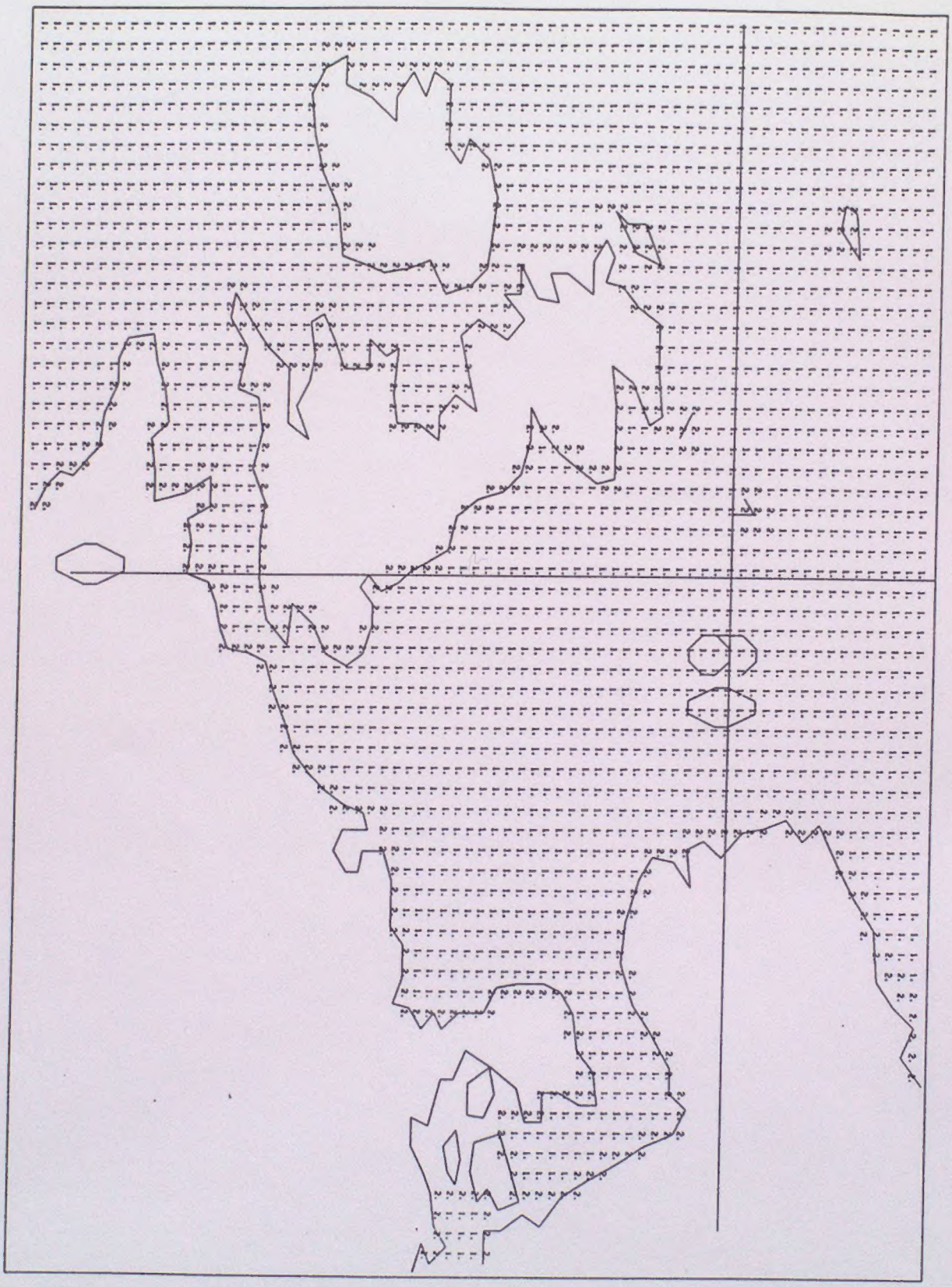

GRIDPOINT TYPES extended EUROPEAN grid
1 = sea 2 = coast
VALID AT 18Z ON 3/3/1993 DATA TIME 18Z ON 3/3/1993

Figure 2a

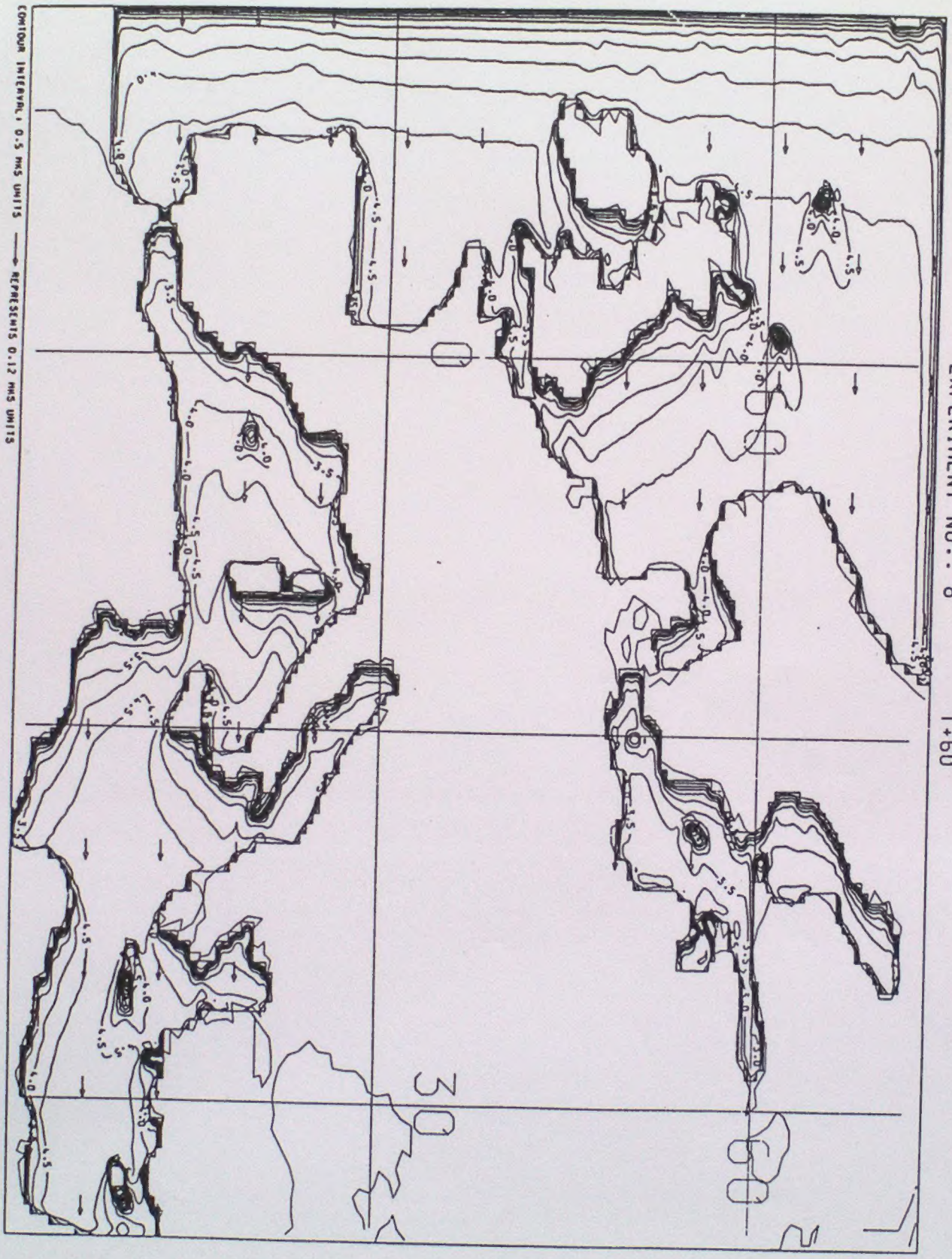
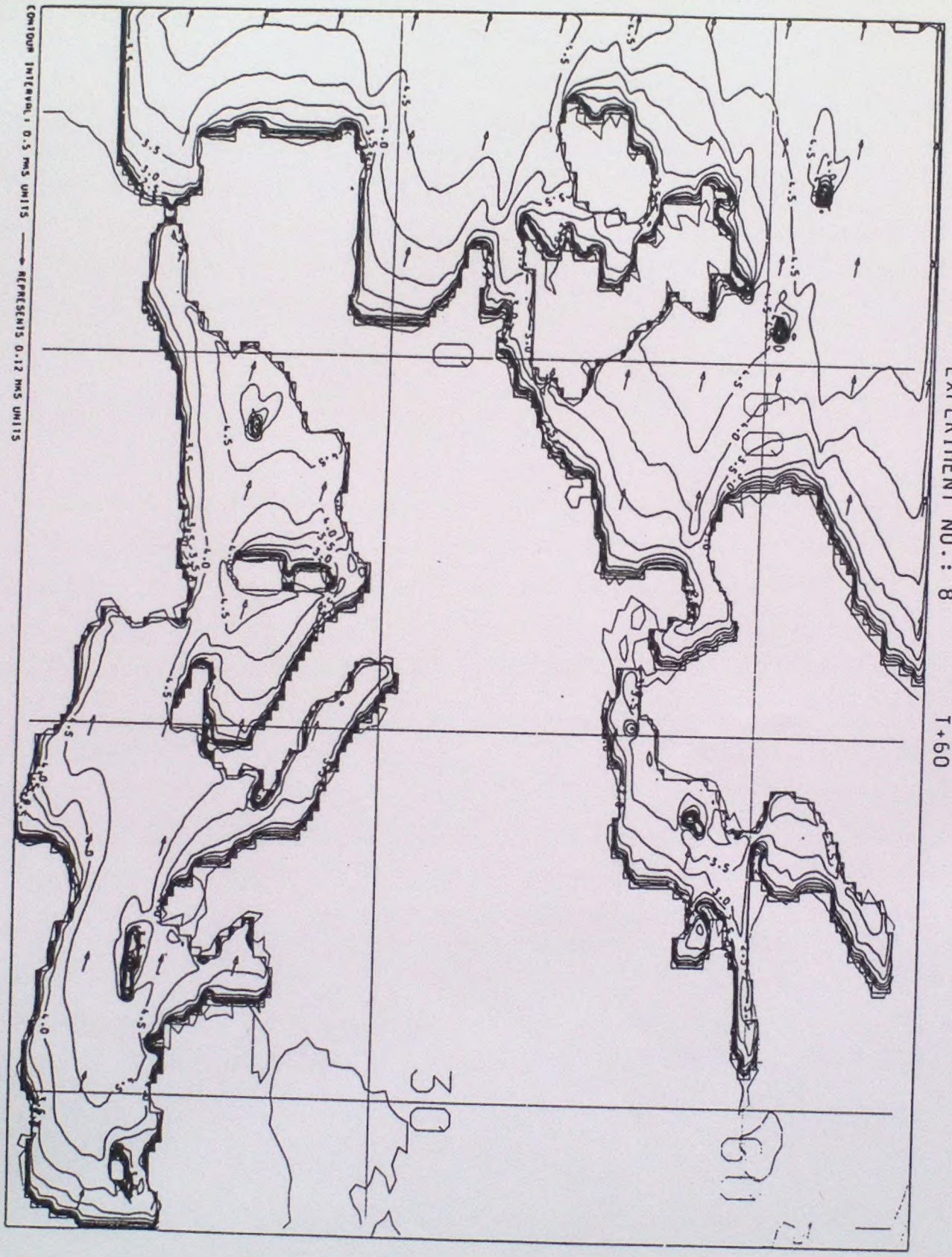

EUROPEAN GRID DEEP FETCH 15M/S 270 DEG
SEA+SWELL CONTOURS (M) / WIND DIRECTION (->) /
VALID AT 12Z ON 3/1/1993 DATA TIME 0Z ON 1/1/1993
SURFACE EXPERIMENT NO.: 8 T+60
CONTOUR INTERVAL: 0.5 RMS UNITS ——→ REPRESENTS 0.12 RMS UNITS
30

Figure 2b


EUROPEAN GRID DEEP FETCH 15M/S 110 DEG
SEA+SWELL CONTOURS (M) / WIND DIRECTION (->) /
VALID AT 12Z ON 3/1/1993 DATA TIME 0Z ON 1/1/1993
SURFACE EXPERIMENT NO.: 8 T+60
CONTOUR INTERVAL: 0.5 RMS UNITS ---> REPRESENTS 0.12 RMS UNITS
30
60

WAVE HEIGHT DIFFERENCE U=15m/s 270 degrees minus U=15 / 260 deg
EUROPEAN MODEL - DEEP WATER
VALID AT 12Z ON 3/1/1993 DATA TIME 0Z ON 1/1/1993
SURFACE EXPERIMENT NO.: 8 T+60

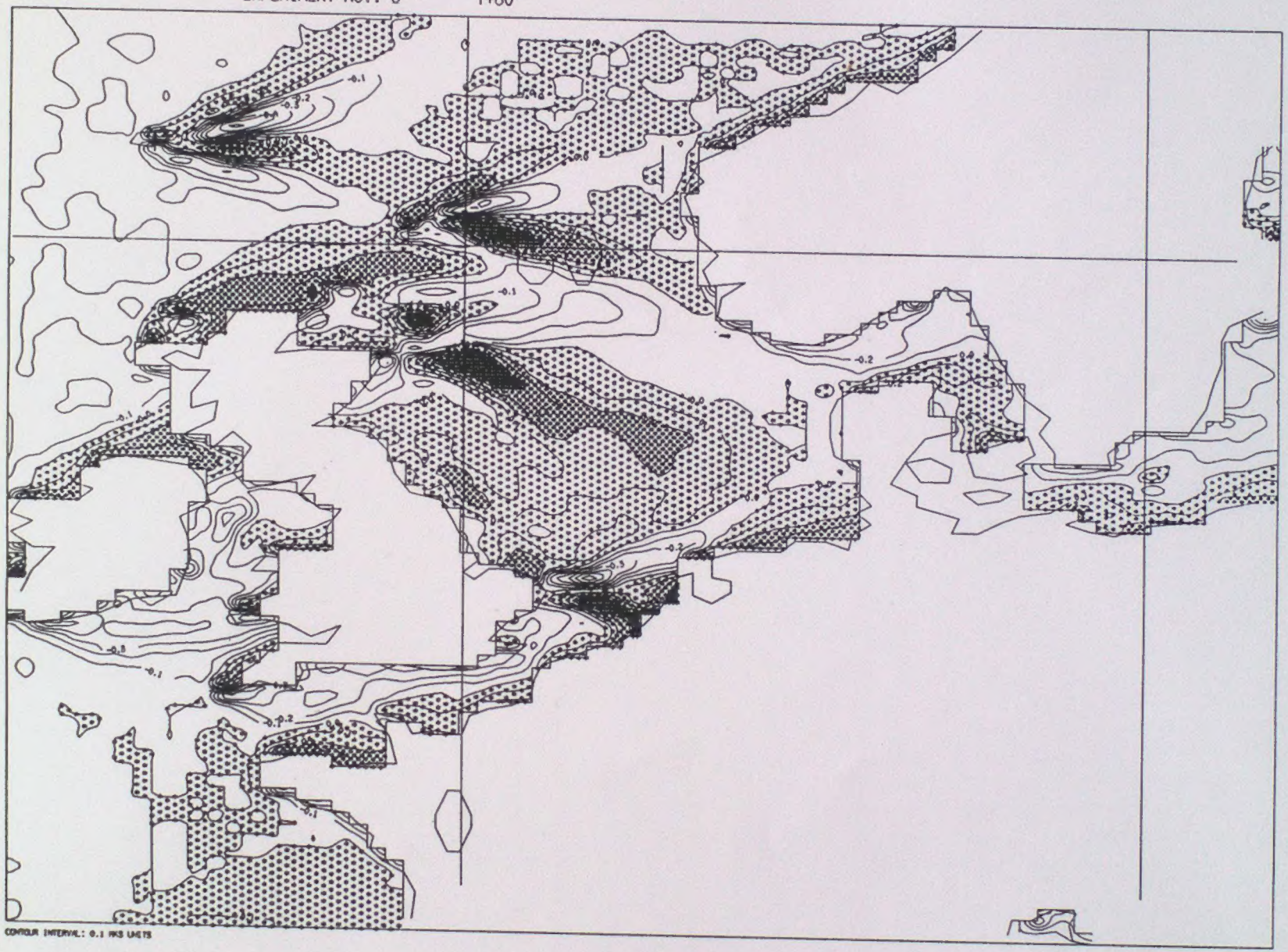


Figure 3a

Figure 3b

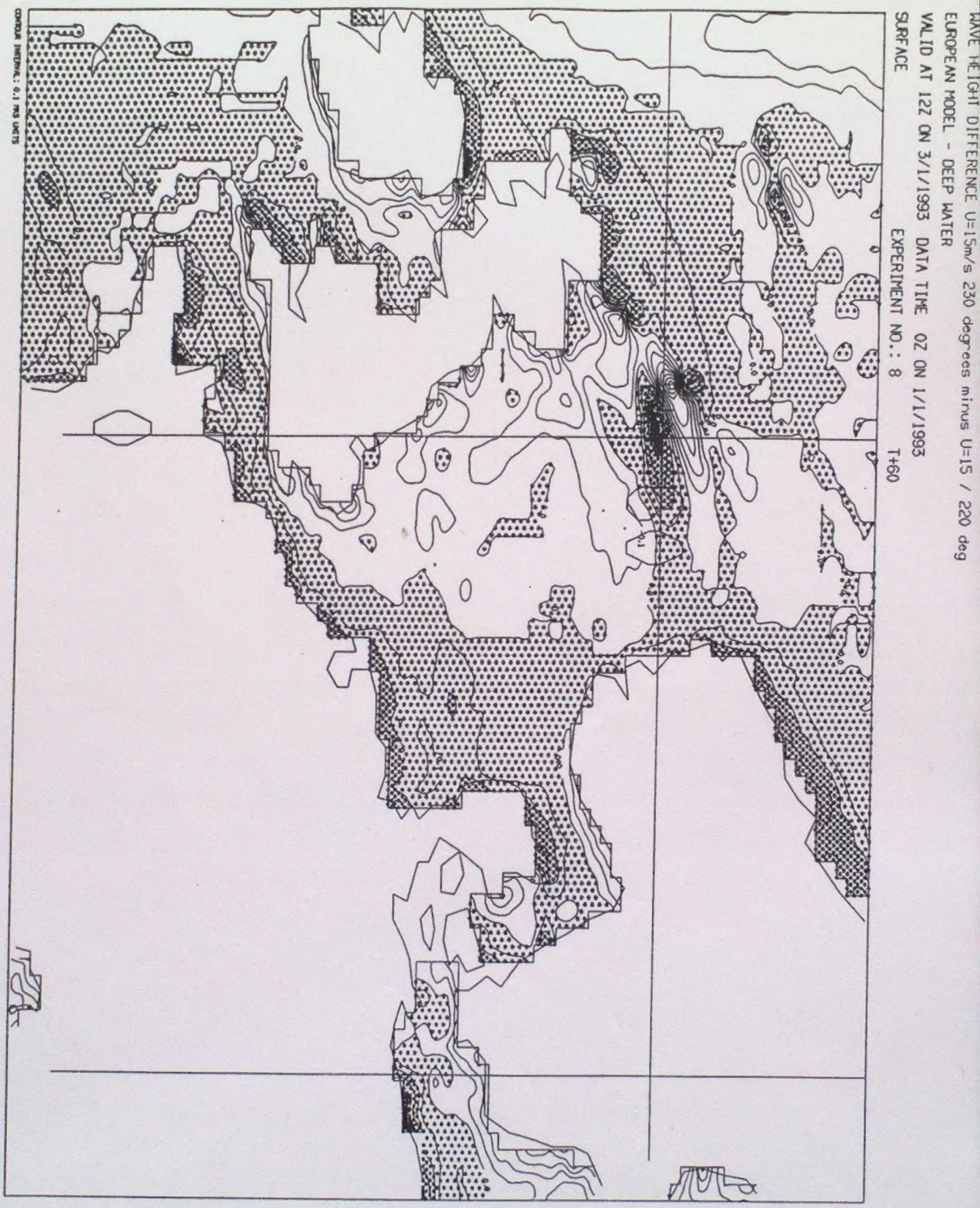
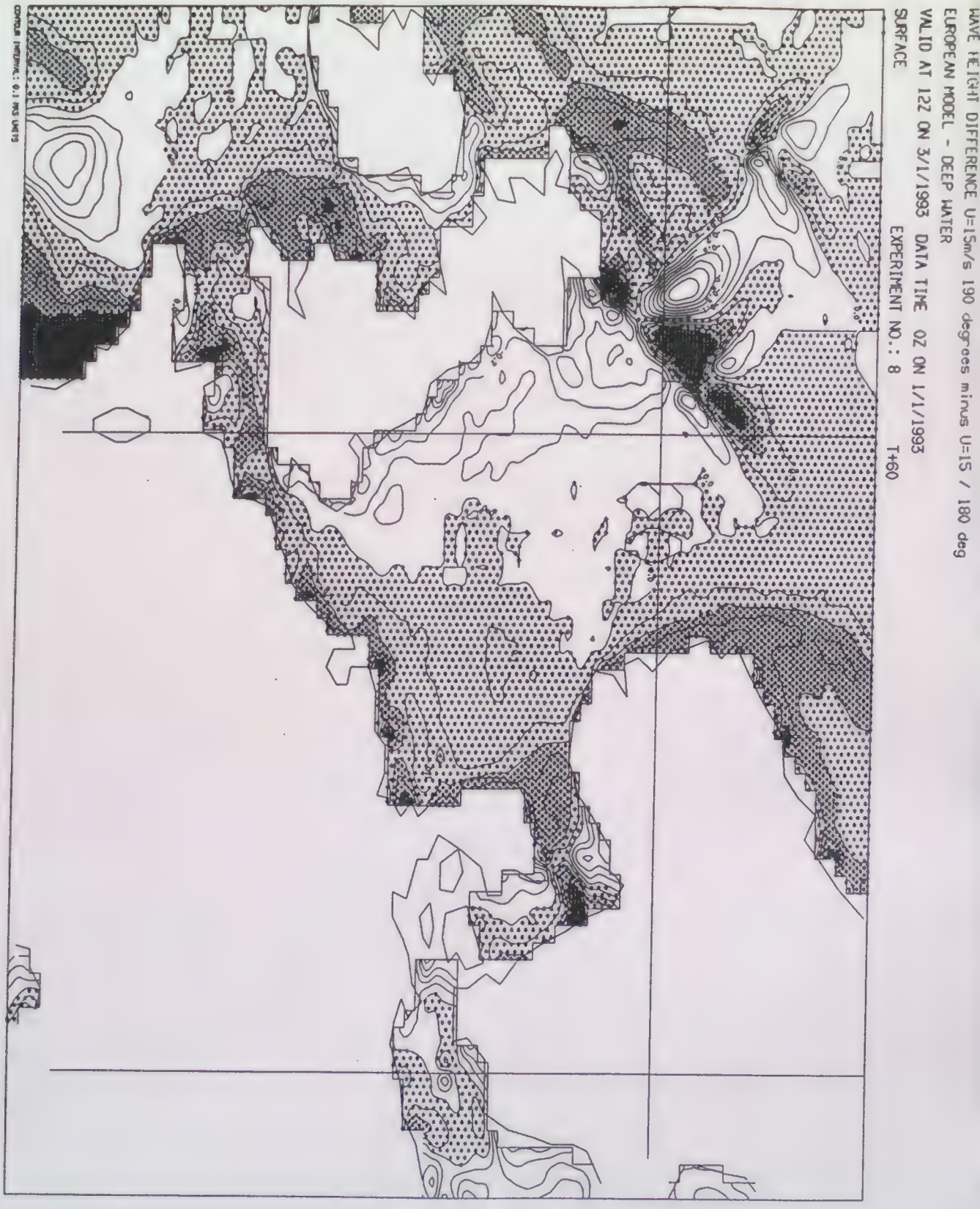

WAVE HEIGHT DIFFERENCE U=15m/s 230 degrees minus U=15 / 220 deg
EUROPEAN MODEL - DEEP WATER
VALID AT 12Z ON 3/1/1993 DATA TIME 0Z ON 1/1/1993
SURFACE EXPERIMENT NO.: 8 T+60
CONTOUR INTERVAL: 0.1 M&S UNITS

Figure 3c


WAVE HEIGHT DIFFERENCE U=15m/s 190 degrees minus U=15 / 180 deg
EUROPEAN MODEL - DEEP WATER
VALID AT 12Z ON 3/1/1993 DATA TIME 0Z ON 1/1/1993
SURFACE EXPERIMENT NO.: 8 T+60
CONTOUR INTERVAL: 0.1 METRES

WAVE HEIGHT DIFFERENCE U=15m/s 170 degrees minus U=15 / 160 deg
EUROPEAN MODEL - DEEP WATER
VALID AT 12Z ON 3/1/1993 DATA TIME 0Z ON 1/1/1993
SURFACE EXPERIMENT NO.: 8 T+60

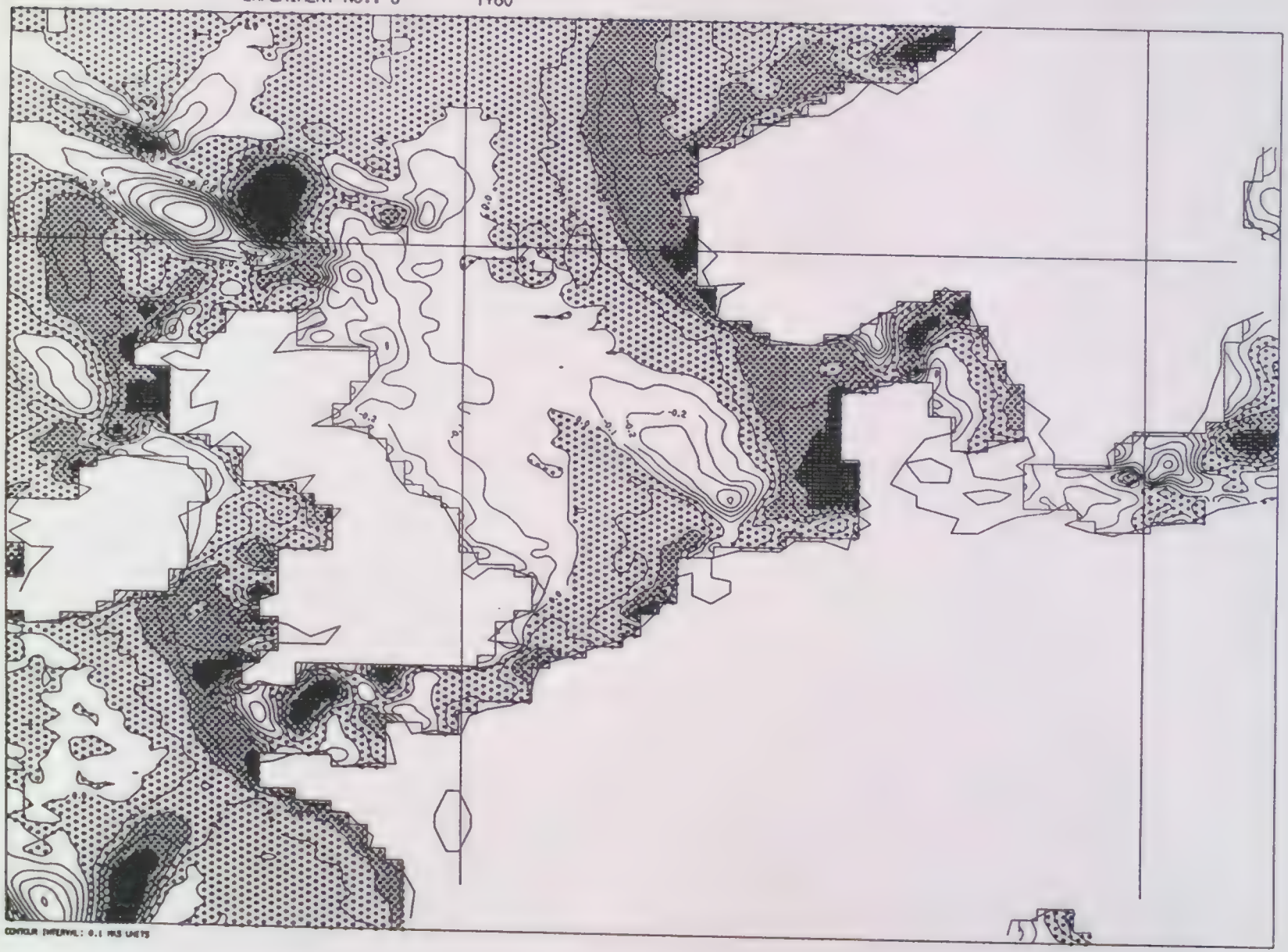


Figure 3d

WAVE HEIGHT DIFFERENCE U=15m/s 080 degrees minus U=15 / 070 deg
EUROPEAN MODEL - DEEP WATER
VALID AT 12Z ON 3/1/1993 DATA TIME 0Z ON 1/1/1993
SURFACE EXPERIMENT NO.: 8 T+60

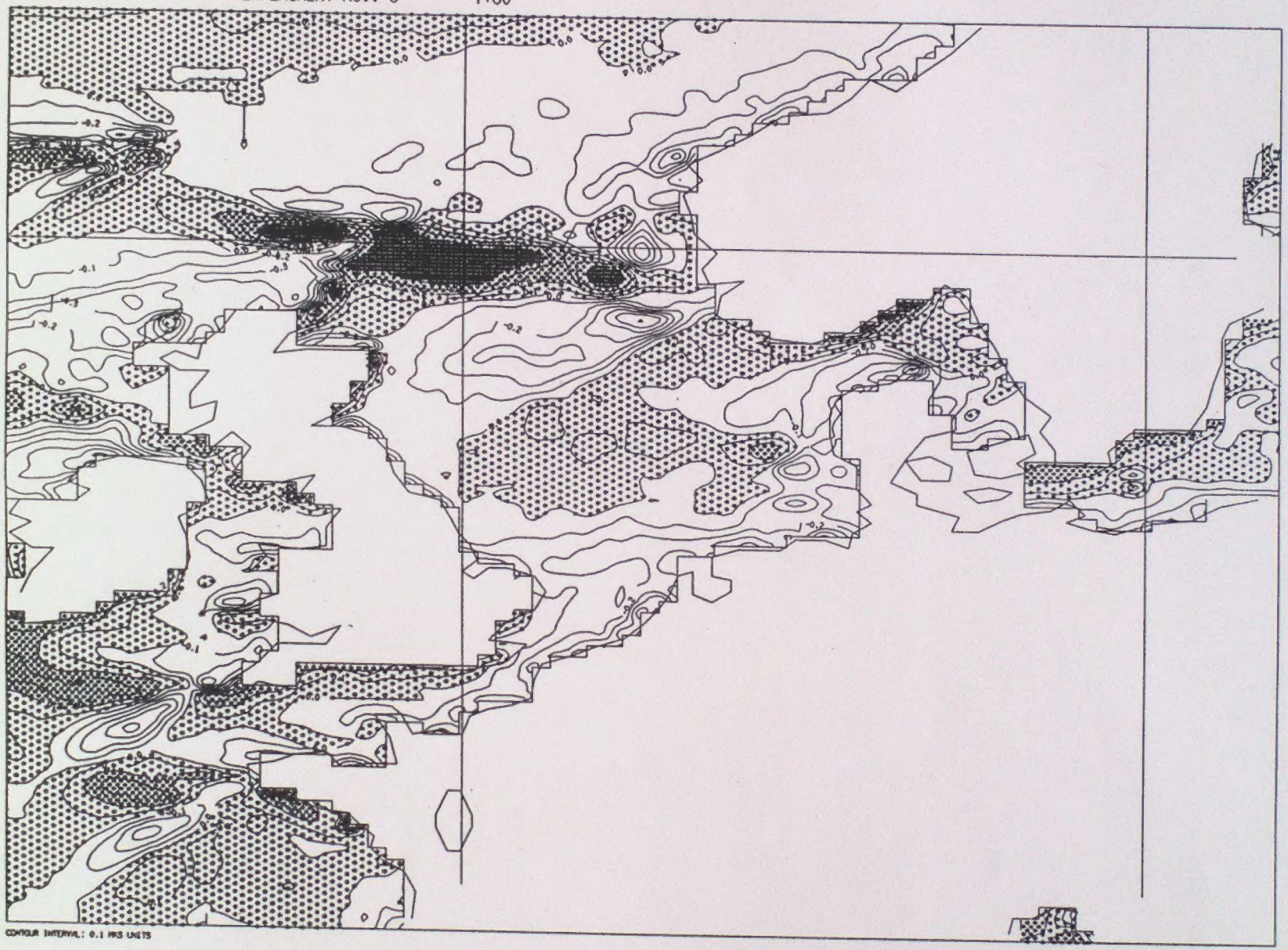


Figure 3e

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